Operational Procedures for the

Thin Film Stress Instrument

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Thin Films
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FLX-2320

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1 INTRODUCTION

The FLX-2320 is a thin film stress machine. A laser scanner is used to measure the changes in the radius of curvature of the substrate caused by the deposition of a thin film on the wafer. This is accomplished by first measuring the wafer curvature before the film is deposited and then re-measuring the curvature after the film is deposited. A well known mathematical relation is then used to calculate the stress of the thin film.

1.1 Purpose

This document will cover the basic theory and operation of some of the most routinely used features of the Thin Film Stress Measurement instrument.

2 Thin Film Stress Instrument

Thin film stress is induced when materials having different coefficients of thermal expansion are bonded together. Stress caused from deposition to a wafer can be tensile (the film is stretched to fit the substrate and causes the edges of the wafer to curl upward) or compressive (the film is larger than the substrate and causes the wafer edges to bow downwards). The FLX-2320, thin film stress measurement instrument determines the stress on the substrate by comparing the curvature before and after deposition. This stress measurement can then be used to make corrections in deposition procedures.

2.1 Components

The thin film stress machine is a tabletop system consisting of a measurement unit, a computer, and a computer keyboard with a built in track ball. **Figure 1** shows the measurement unit components with the door shut and **Figure 2** shows the inside of the cabinet.

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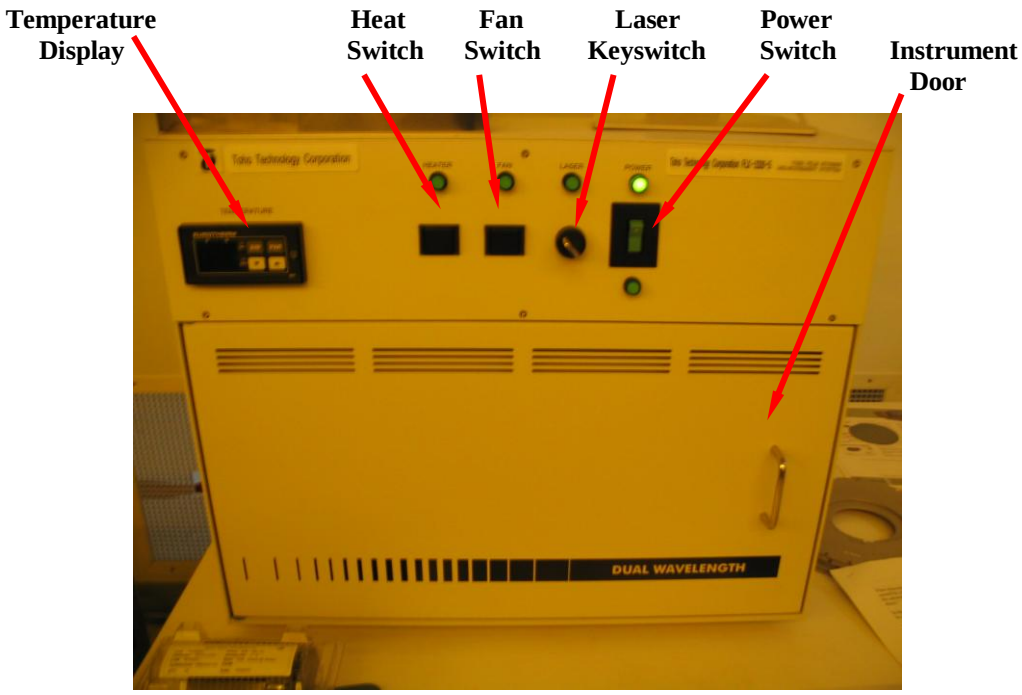

Figure 1: Photograph of the measurement unit. Shows the instrument panel with the door closed.

Temperature Display: Displays the temperature cooling and heating cycle, used in the stress temperature mode.

Heater Switch: Turns heater on for stress temperature measurements.

Fan Switch: Turns the fan on/off. Must have the fan on for stress temperature measurements.

Laser Keyswitch: Turns the laser on/off. Must be in the **On** position when in operation.

Power Switch: Must be in the **On** position for operating this instrument.

Instrument Door: Door must be closed for the instrument to operate.

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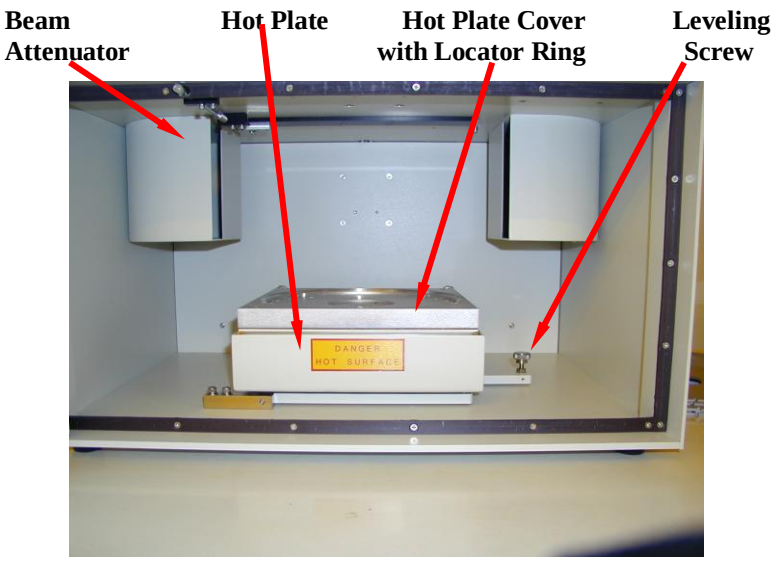

Figure 2: Inside of the instrument cabinet.

Beam Attenuator: Blocks the laser beams mechanically when the door is opened.

Hot Plate: Used in the stress temperature mode.

Hot Plate Cover with Locator Ring: This is where the wafer is placed (see **Figure 3a**).

Leveling Screw: Used to level the instrument when relocated.

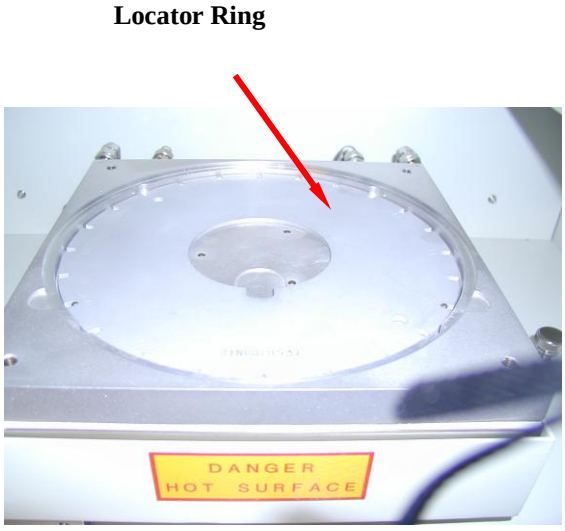

Figure 3a: Ring Locator, used to position the wafer. Notched edges indicate angle of rotation – used for creating 3-D deflection graphs.

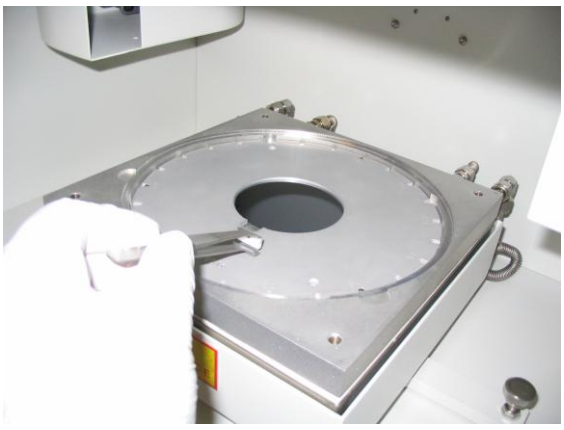

Figure 3b: Wafer in Ring the Locator.

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The Locator Ring is used to position the wafer in the instrument. Positioning the wafer correctly is crucial; the instrument will not make any measurements when the wafer is improperly inserted. Place the wafer in the ring with the notch to the front. The wafer should sit flat in the locator ring. To create a three-dimensional view of the wafer stress, the locator ring can be repositioned in 30° increments. Measurements can be taken from 0° to 180° to produce the 3-D graph.

2.2 Theory

The thin film stress instrument measures the changes in the radius of the curvature of the wafer caused by a deposition of thin film. The stress of the thin film is calculated from this measurement using the given equation and variable explanation:

$$\sigma = \frac{Eh^2}{(1 - v)\,6Rt}$$

$\frac{E}{(1 - v)}$	biaxial elastic modulus of the wafer (1.805E11 PA for 100 silicon wafer)
E	Young's modulus, defined as stress/strain
v	Poisson's ratio
h	wafer thickness (m)
t	film thickness (m)
R	wafer radius of curvature (m)
σ	average film stress (Pa)

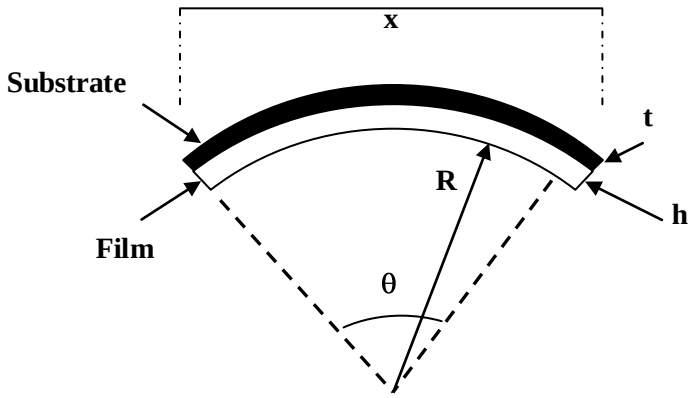

Figure 4: **Drawing of substrate deformed to radius R by the film deposition.**

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The value of R is the effective radius. It is obtained from the measurements both before and after thin film deposition. R1 is the average radius of the substrate before deposition. It is calculated by measuring θ as a function of x and a line regression. R_2 is the radius after deposition and is proportional to 1/R. In equation format:

$$\frac{1}{R} = \frac{1}{R_2} - \frac{1}{R_1}$$

which can be rearranged to obtain **R**, the effective radius.

$$R = \frac{1}{\frac{1}{R_2} - \frac{1}{R_1}} = \frac{(R_1 R_2)}{(R_1 - R_2)}$$

2.2.1 Additional Calculations

Calculations and additional details on the diffusion, elastic, and the expansion coefficients can be found in section 9-3 of the User Manual.

2.3 Measurements

The FLX-2320 measures the deflection (bowing) of a wafer using a laser beam. The laser makes two complete passes across the wafer. An initial measurement reference, with no film, is required to calculate the deflection resulting from the thin film deposit. The collected and calculated data is compiled in a spreadsheet format. The visual results can be viewed in graphic form.

Thin film stress will be either tensile or compressive stress. If the film has tensile stress, its atoms are farther apart than they would like to be. The film will try to contract, bowing the substrate, resulting in a concave appearance. (The film is being stretched to fit the substrate.) Tensile stress may result in microcracking of the thin film. If the film has compressive stress, the film will try to expand, causing the substrate to bow the film in a convex manner. (The film is compressed to fit the substrate.) Compressive stress may result in buckling. See **Figure 5**.

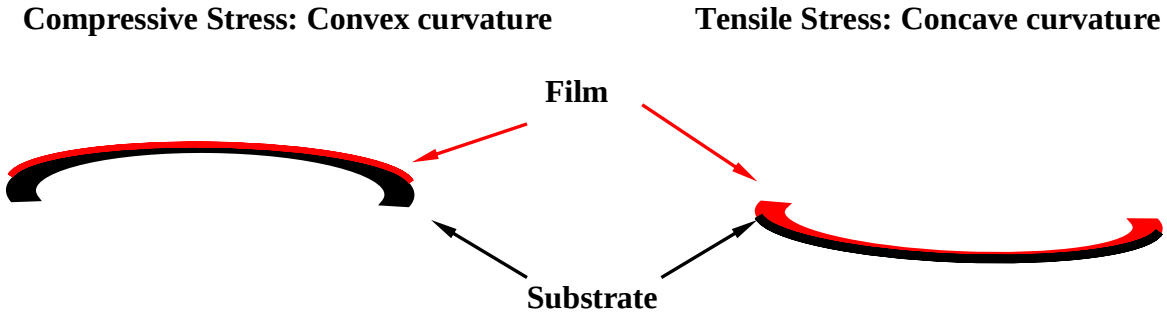

Figure 5: Stress Diagrams (Film is in red, substrate is in black)

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3 PROCEDURE

Before taking stress measurements with the FLX-2320, it is important to note a few key details.

1. This instrument works only on blank wafers, patterned wafers will not work.
2. The surface of the wafer must be reflective for the laser to bounce back into the detecting device. Rough surfaces will affect the measurement.
3. The film stress measurement is inversely proportional to the square of the wafer thickness. Therefore, the wafer thickness must be measured before using the FLX-2320. Accuracy of this measurement should be in the hundred micrometer range.
4. Measure the wafer both before and after depositing a film. Film stress is calculated using by comparing both measurements.
5. Proper placement of the wafer in the locator ring is crucial for the instrument to function. Verify that the wafer is in the correct position before closing the cabinet door.
6. DO NOT open the cabinet door while the wafer is being measured.

3.1 Measuring Wafer Thickness

The wafer thickness is a required field for operating the FLX-2320. Any tool that can accurately calibrate the thickness of the wafer will work. The Ultra Digit Mark IV, a stylus micrometer, is ideal for this task. This tool uses a stylus to take measurements and displays the reading in an LCD face in either inches or millimeters (mm will be used for the FLX-2320).

Figure 6: Ultra Mark IV (micrometer) Used to measure wafer thickness. Easy to read liquid crystal display face. Readings can be taken in inches or millimeters.

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Figure 7: Operating the micrometer

1. Place the micrometer on a level surface. Turn on the device. Set the display reading to mm.

2. Before taking a measurement of the wafer, zero the micrometer. This is accomplished by lifting the stylus and releasing it. Adjustments are made using the front knob.

3. Lift the probe and place the desired wafer on the stage of the micrometer.

4. Lift the stylus and gently release. The reading will appear on the display.

3.2 Operating the Thin Film Stress Instrument

The PC for the stress instrument uses WINDOWS 3.1. It controls the measurements, data accumulation, and calculations. To begin using the stress machine, the power switch and the laser keyswitch must be in the on position. The hot plate will not be used for normal stress measurements. Place the wafer flat in the locator ring (see **Figure 3b**) and shut the instrument door.

The following procedure is used for maneuvering within the parameters of the computer program.

1. Double click on the Winflx icon.

2. Select a user name or create a new user (see **Figure 8**).

Figure 8: User Login. Select a user or create a new one.

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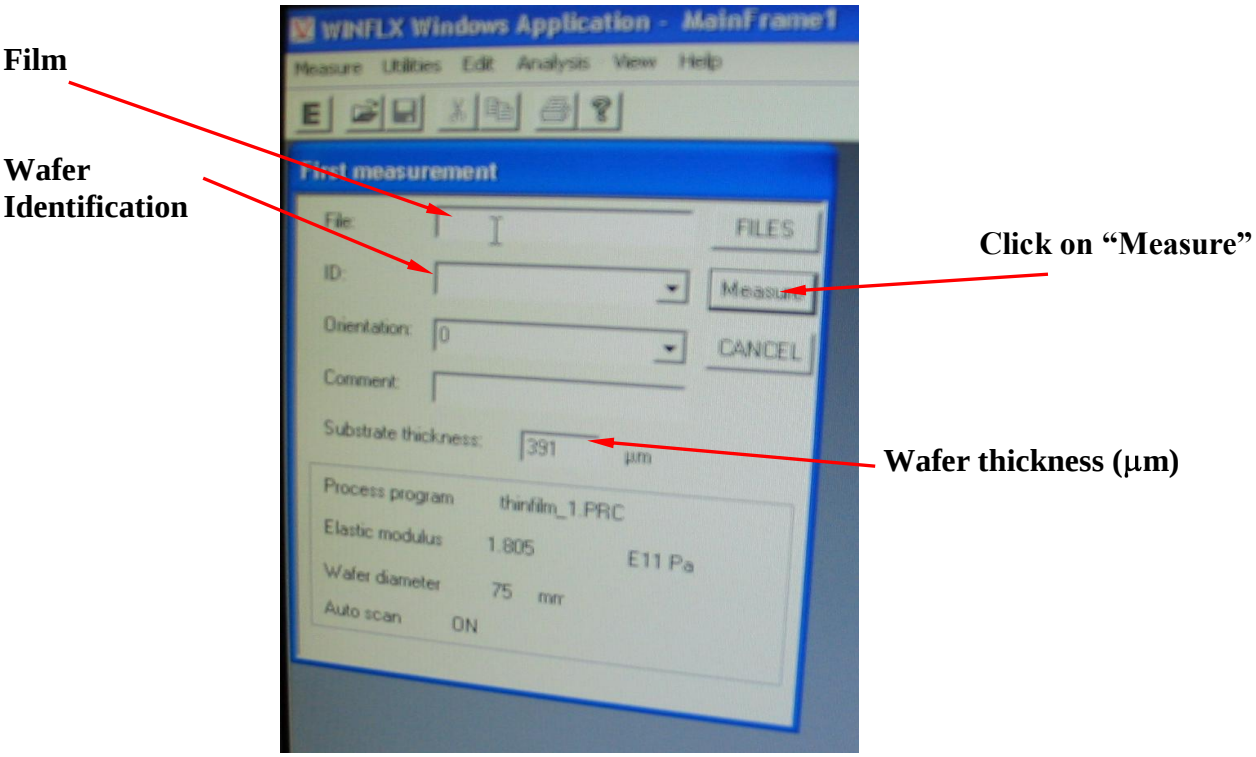

Figure 9: First Measurement

3. Double click on the Winflx icon.

4. Select a user name or create a new user (see **Figure 8**).

5. Select "Measure" from the pull down menu, click on "First". The window in **Figure 9** will appear. This will be the measurement prior to film deposition.

6. Select or enter a file name. One file name can be used for many wafers or a new file name can be given to each wafer. Double click on your selection.

7. Enter the information on the remaining fields. ID is to identify the wafer, Orientation is the orientation of the wafer, Comments can be used for additional information, and Substrate thickness is the measurement taken using the micrometer.

8. Click "Measure" in the "First Measure" dialog box. The instrument will start and you will hear a series of beeps. When the process is complete, a graph of the substrate deflection will appear.

9. To save a graph to a data file, choose "Save As" form the file menu and enter the name for the graph and click "OK". If the sample is measured again using the same ID, a second record is created and saved without overwriting the first. For calculations, the last measure will be used.

8. Close all windows and exit the program. This completes the reference measurement.

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Measuring the wafer after film deposition

9. Measure the thickness of the wafer using the micrometer. Place the wafer on the locator ring and close the cabinet door

10. Follow steps 1 and 2 listed above. This time, choose "Single" from the "Measure" menu. Enter the fields in the dialog box. A particular wafer can be selected from the ID pull down menu. Enter the correct wafer thickness and any relevant comment, such as type of film deposit.

11. Click "Measure" and the instrument will start as in step 6. Repeat steps 7 and 8.

3.3 Deflection Maps

A 3-D view of the deflection over the wafer can be created by taking several measurements at different angles. Both before and after deposition of film measurements can be used to create this graph. To create this 3-D view, the wafer is measured at incrementing angle (0° to 180° with 30° increments works well). After each measurement, the wafer is removed from the cabinet and the locator ring is rotated (see **Figure 3**).

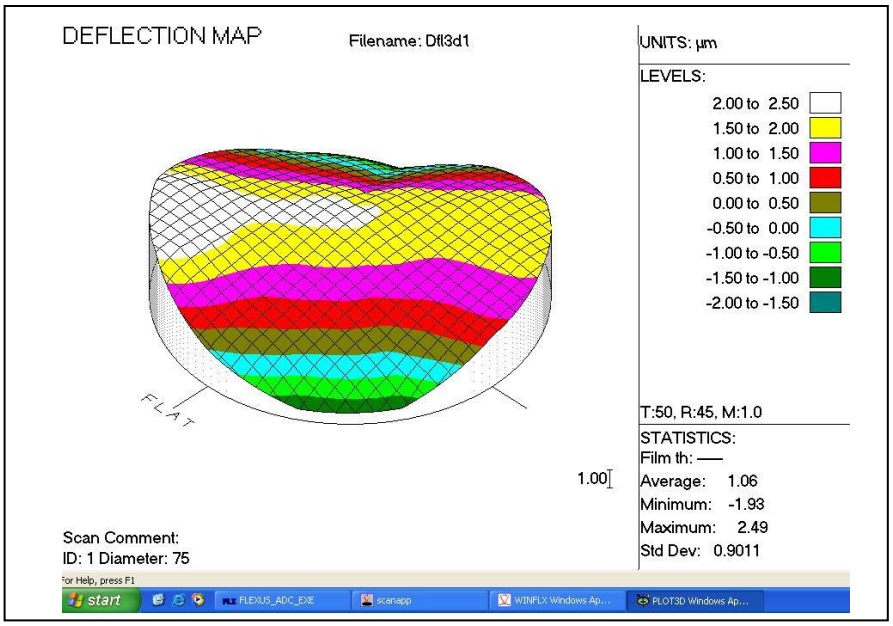

Figure 9: 3-D deflection graph of a wafer. For this graph, 30° increments were used to measure the wafer. The different levels of stress are color coded across the wafer.

The procedure for creating the 3-D deflection map can be found in the User Manual (Section 7.5.1). User Manual is located at the stress machine station.

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4 CONCLUSION

The FLX-2320 is a thin film stress instrument that uses a laser scanner to measure the changes in the radius of the curvature of the substrate caused by deposition of a thin film on a wafer. The procedure for the most common use, finding the deflection of a wafer due to a thin film deposition, is outlined in this paper. Other functions of the thin film stress instrument are the stress temperature mode, for which the hot plate is used and time stress mode. The details of these functions and the related data collection can be found in the User Manual (located at the stress machine station).

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